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Studying local species assemblages of salt-affected vegetation for monitoring Natura 2000 habitats

Matilde Gennai[1], Claudia Angiolini[2], Andrea Bertacchi[3], Antonio Gabellini[2], Simona Sarmati[4], Daniele Viciani[1], Bruno Foggi[1]

1 *Department of Biology, University of Florence, via G. La Pira 4, I-50121, Italy*

2 *Department of Life Sciences, University of Siena, via P.A. Mattioli 4, I-53100, Italy*

3 *Department of Department of Agriculture, Food and Environment University of Pisa, Via del Borghetto 80, I-56124, Italy*

4 *Department of Sciences, University of Roma Tre, Rome, Viale G. Marconi 446, I-00146, Italy*

Corresponding author: Bruno Foggi (bruno.foggi@unifi.it)

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Abstract

This study aims to characterize saline habitats of the Tuscan coast based on the Natura 2000 Habitats Directive 92/43/ECC. These habitats include Atlantic salt meadows (1330), Mediterranean salt meadows (1410) Mediterranean and thermo-Atlantic halophilous scrubs (1420), and Mediterranean salt steppes (1510). We compiled vegetation data from a total of 418 plots carried out during our own fieldwork (N = 157) and published scientific literature (N = 261). We performed a Linear Discriminant Analysis to associate species to habitats and used the phi coefficient of association to identify diagnostic species of each habitat. For each habitat, we provide a regional syntaxonomic framework, constant species, cover coefficients, diagnostic species (phi) and "typical species". We identified groups of species, that we called "local assembly of typical species", composed by species with a phi coefficient > 20 and/or a cover coefficient > 50 that can be used to identify the habitats and to monitor their conservation status at the local level. This study revealed differences in the "local assembly of typical species" among habitats, characterized by fewer species in habitats 1420 and 1510, and many species in habitats 1410 and 1310. Our results showed that the habitat 1510 was recognizable only for the high cover value of *Limonium narbonense* and, at least in Tuscany, its syntaxonomic attribution to the order *Limonietalia* is uncertain. We tested this approach only for a few habitats, but a broader applicability based on other habitats is desirable.

Keywords

Crypsietea aculeatae, Habitats Directive, *Juncetea maritimi*, monitoring, *Salicornietea fruticosae*, *Saginetea maritimae*, *Therosalicornietea*, typical species

Introduction

The Habitats Directive 92/43/EEC is one of the most important tools for nature conservation in Europe. This Directive obliges the Member States of the European Union to protect endangered habitats within the Natura 2000 network, listed in the Annex I. Some sites hosting Natura 2000 habitats are defined as Special Areas for Conservation (SACs) and their conservation is of high priority at the national level. Conservation efforts aim to actively maintain SACs in a "good state of conservation" based on suitable management plans that rely on reasonable monitoring plans (Evans and Arvela 2011; Maccherini et al. 2020).

But which parameters need to be surveyed to verify the efficacy of conservation measures is scarcely known. According to the European Commission (1992), the evaluation of the conservation status of SACs and other Natura 2000 habitats is based on several criteria, such as: area, range, structure and functions, and prospects. If these factors are favourably evaluated, the habitats are in a good state of conservation. Area and range of habitats are assessed at a large scale (Bonari et al. 2021), while parameters such as structure, function, and typical species

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(composition) should be studied at the same local scale as the conservation measures that are implemented. In Italy, information on these three aspects can be found only in the national manuals for habitat interpretation (i.e., Biondi and Blasi 2009; Biondi 2013; Gigante et al. 2016), but is still missing at the local level. Administrative Regions bear the responsibility for the Natura 2000 site management, especially SACs; thus, the manuals should also take into consideration the local scale, which is the Administrative Region in our case.

Habitat structure is related to its physiognomic features, while habitat functions depend on the presence of certain species. Both aspects are related to the occurrence of typical species. According to Evans and Arvela (2011), typical species "should be selected to reflect favourable structure and functions of the habitat type". Unfortunately, so far, no definition of a typical species assemblage exists. According to Maciejewski (2010) "Le terme espèce typique n'est pas défini dans la DHFF et il ne correspond pas à aucune notion scientifique" (The term "typical species" is not defined in the DHFF - Habitat Directive in French ndr - and it does not correspond to any scientific concept). However, Bonari et al. (2021) state that it is important to well define the typical species for each habitat type, and this requires a solid knowledge on the different ecosystems. According to European Environment Agency (2017), typical species occur regularly in the given habitat types and are good indicator species for a favourable habitat quality.

According to Bonari et al. (2021), the results of phytosociological analyses are adequate for habitat monitoring (77% of the surveys). Accordingly, the phytosociological approach can help during the selection of species groups. From these species groups, typical species for the habitat (sensu Evans and Arvela 2011) can be extracted. Groups of species were already listed in the manuals by Biondi and Blasi (2009 sub: "combinazione floristica di riferimento"), European Environment Agency (2021 sub: "typical species") and Angelini et al. (2016, 2018; sub: "specie tipiche"). However, it remains unclear whether these species are useful to recognize habitat types or to define a good habitat status. Furthermore, the typical species mentioned in the above listed manuals are not based on any quantitative data or data analysis. Thus, we do not know if a habitat type and its conservation status can be effectively identified just from the presence of certain species. According to Maciejewscki (2010), in addition to the presence of species, their abundance should be reported in the "typical species" list, while, on the contrary, the lists found in various manuals lack of abundance data, apart Chytrý et al. (2020) that report a statistically-derived species combination of Eunis Habitats.

In addition to the typical species, species that have a negative impact on the habitat quality can occur. These could also be utilized for the evaluation and monitoring of the status of plant communities occurring in Natura 2000 habitats. The species belonging to this group are for example alien species, weeds or ubiquitous species whose presence is not strictly linked to the ecological characteristics of a given habitat.

The occurrence of groups of species that we consider negatively and positively related to the assessment of habitat quality, depends on site-specific ecological features such as microclimatic characteristics, soil properties, but also on management practices. Many of these parameters change at the local scale. Thus, the "positive" and "negative" species should be detected at this scale. Following Delbosc et al. (2021), local data represent valuable sources of information for testing the methodological approach and are essential to assist decision-makers in planning resources conservation strategies for SACs and other habitats. According to Angiolini et al. (2017), there is a "need to consider local singularities and to adapt global criteria to the local situation when setting conservation priorities". Furthermore, Ellwanger et al. (2018) reported that in identifying monitoring schemes for European habitats, the majority of efforts focused on local sites (e.g. conservation areas) or regions (e.g., administrative regions).

In 2017, the Tuscan Regional Administration (Italy), together with a group of researchers from the three local universities (Pisa, Siena and Florence), launched two projects (MONITORARE, 2017-2018 and NAT-NET, 2019-onwards) aiming to develop a database for monitoring the state of plant and animal species and for the habitats listed in the Annex I of the Habitats Directive. Within these projects, following the Italian manual (Angelini et al. 2016) and the Habitat Directive (European Commission 1996, 2013; Biondi and Blasi 2009; Delbosc et al. 2021), several habitats were studied by establishing over a thousand georeferenced vegetation plots.

In this paper, we present our study on saline habitats, located in the back dunes, around the lagoons, or in the depressions near the sea in the Tuscany region. Saline habitats are one of the least studied habitats among the coastal ecosystems (Delbosc et al. 2021). Their conservation status worsened due to inappropriate agricultural practices and their close proximity to cultivated lands that adversely alter moisture balance and salinity conditions (Landi and Angiolini 2015). However, compared to sandy ecosystems (Maccherini et al. 2020; Prisco et al. 2020), coastal saline habitats seem to suffer less anthropogenic pressure.

Our study aims are to i) define the phytosociological groups at the alliance level and their relation to Natura 2000 habitat types 1330, 1410, 1420, and 1510 and to ii) identify species groups for each of the studied Natura 2000 habitat types. These species groups can be used to recognize the habitat and to indicate the success of the respective management. They can be applied as an "easy-to-use method for monitoring" (Pätsch et al. 2019) and an alternative to the survey of the whole floristic composition of the studied habitat types.

Materials and methods

Study area

Our study area is Tuscany (Italy). Our relevés spanned from the Selva Pisana in the north until the Laguna di Orbetello in the south (Fig. 1). Our relevés were placed in Regional Protected Areas, partly coinciding with SACs belonging to the Natura 2000 network. The macrobioclimate is Mediterranean with upper mesomediterranean thermotype and ombrotypes ranging from upper humid to upper dry (Pesaresi et al. 2017).

The target vegetation types included the following habitats: 1310 - Salicornia and other annuals colonizing mud and sand, 1410 - Mediterranean salt meadows (*Juncetalia maritimi*), 1420 - Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornietea fruticosi*), and 1510 - Mediterranean salt steppes (*Limonietalia*), the latter being a priority habitat type of conservation interest.

Plot-based data and data analysis

We gathered a dataset comprising a total of 418 relevés (Suppl. Material 1, Table S1), of which 157 were carried out by the authors between 2018-2021, for the purposes of monitoring activities following Art. 17 of the Habitats Directive. Additionally, data from 261 plots were derived from published scientific literature. The distribution of the relevés is illustrated in Fig. 1. Data concerning the localities of the sampled sites and the correspondence between data and references are reported in Suppl. Material 2, Table S2.

The position of our own plots (each of 4 m^2) was selected by stratified random sampling in each of the SACs. The locations of the SACs were indicated in the EU habitat maps provided by the HaSCITu (Habitats in the Sites of Conservation Interest in Tuscany) program of the Tuscan Regional Administration (Regione Toscana 2018). After surveying the available scientific literature, only the relevés that were taken between 2000 and today and an area < 50 m^2 were retained for our analysis.

Species occurring less than 4 times across all relevés were deleted, resulting in a final table consisting of 418 relevés and 84 (out of the originally 152) species. The Braun-Blanquet cover-abundance scale was transformed according to the ordinal scale proposed by van der Maarel (1979) and Noest et al. (1989): (r = 1; + = 2; 1 = 3; 2 = 5; 3 = 7; 4 = 8; 5 = 9) to have a linear scale and ensure comparability of data from different sources taken using different cover-abundance scales.

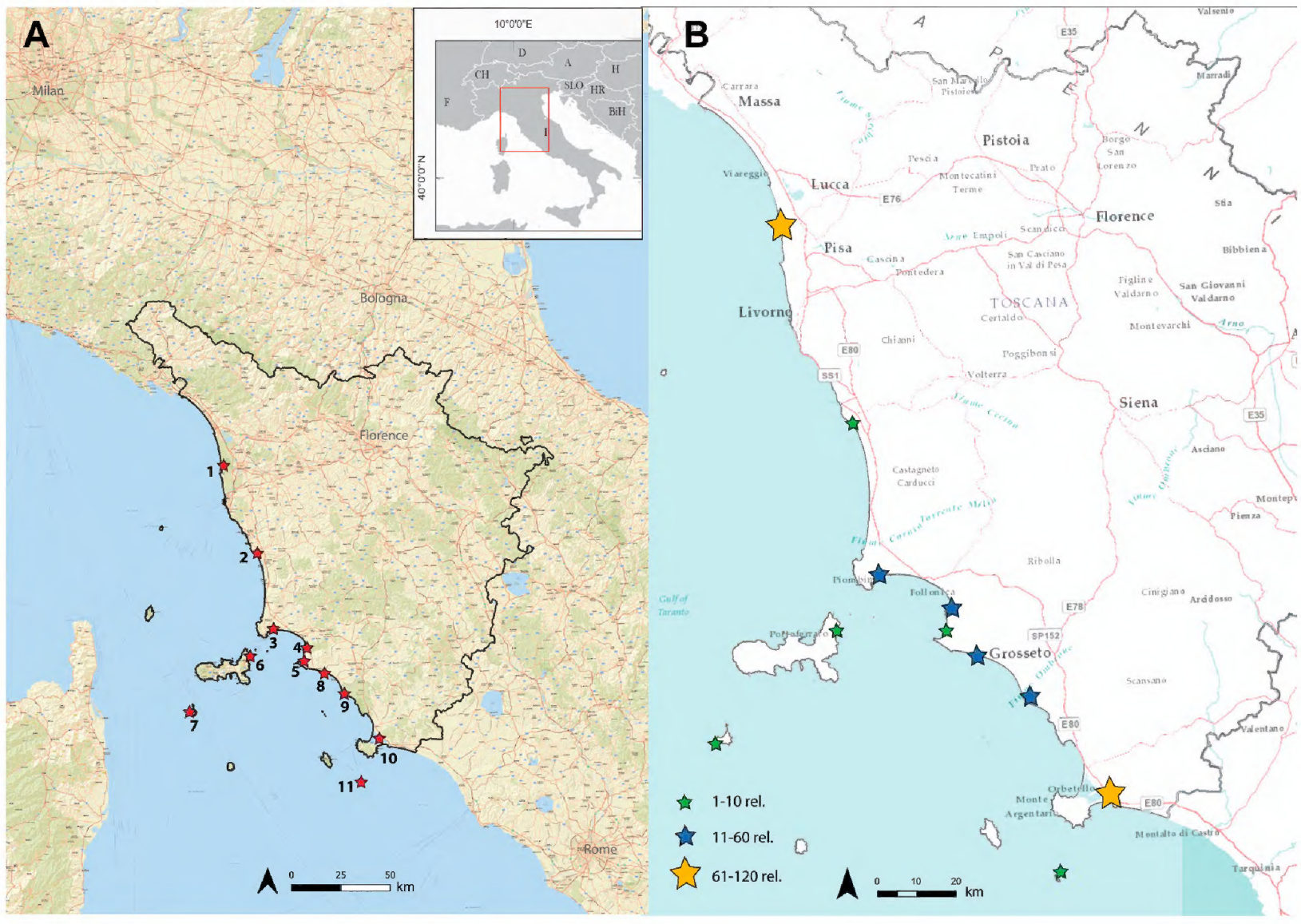

Figure 1. A: Distribution map of the salty and muddy areas of Tuscany Sites detected: 1 - Cornacchiaia, Galanchio, Bozzone Reserve, San Rossore; 2 - Vada; 3 - Venturina (Orti-Bottagone marsh); 4 - Scarlino marsh; 5 - Pian d'Alma marsh; 6 - Elba Island (Saline San Giovanni); 7 - Pianosa Island; 8 - Castiglione della Pescaia (Diaccia Botrona marsh); 9 - Trappola-Bocca d'Ombrone-Porto Vecchio; 10 - Orbetello lagoon; 11 - Giannutri Island. B: Number of relevés for each site considered. Data concerning the localities of the sampled sites are reported in Suppl. Material 2.

The relevés-species matrix (Suppl. Material 1, Table S1) was analysed performing a LDA (Linear Discriminant Analysis) in the software PAST 3.14. LDA tests the assignment of each relevé to a given habitat, which in our case was either indicated in the original literature, or, in case of our own data, assigned during the data sampling. The diagnostic species of each habitat were statistically calculated by computing the "phi coefficient of association" based on presence/absence data (Chytrý et al. 2002). The significance of this fidelity coefficient was calculated according to a Fisher's exact test. We considered a species as diagnostic when phi > 20 and $p < 0.01$ (Douda et al. 2016). For each habitat, we reported species that had a phi coefficient > 20 and/or a cover coefficient (sum of the central cover values divided by the number of relevés in the table x 100, Géhu 2006) > 50, together with their frequencies. All these values were calculated on our dataset and are therefore valid only at the local scale. Thus, the here identified groups of species, hereafter "local assembly of typical species", will be useful for the recognition of the saline habitats in the wild and for monitoring their conservation status in Tuscany. Also, only for comparison, we added the species reported by Biondi and Blasi (2009; sub: "combinazione floristica di riferimento"), European Environment Agency (2021; sub: "typical species"), European Commission (1996; 2013), Angelini et al. (2016, 2018; sub: "specie tipiche") and Regione Toscana (Regione Toscana 2018; sub: "specie indicatrici").

Species taxonomy was retrieved from Acta Plantarum (Acta-Plantarum 2021); the names of syntaxa above the association level follow Mucina et al. (2016). The delimitation of habitats follows Biondi and Blasi (2009), European Commission (2013), Angelini et al. (2016) and the Tuscany Region website (Regione Toscana 2018).

Results and discussion

The results of the LDA are displayed in Fig. 2. The first two axes of the LDA represented 86.34% of the variation (eigenvalues of 8.23 and 5.97, respectively). The scatterplot highlighted a clear separation of habitat 1310 from all the other habitats, notwithstanding its intrinsic heterogeneity. The core of habitat type 1410 was found in the third quadrant, except for a very few relevés that partially overlapped with the habitat 1420. All relevés of the habitat 1510 were found in the area delimited by the relevés belonging to the 1410 habitat. Finally, the relevés of the habitat 1420 were found in the first and second quadrant.

Syntaxonomic framework

Habitat 1310: The vegetation types reported for this habitat relate to several associations (at least 13 vegetation types, depending on the different interpretations of the syntaxonomic level), of three phytosociological classes: *Crypsietea aculeatae*, *Therosalicornietea* and *Saginetea maritimae*. Four types described for the coast of Tuscany were dominated by *Salicornia perennans* Willd. (*sub: S. patula* Duval-Jouve) and/or *S. procumbens* Sm. (*sub: S. emerici* Duval Jouve and *S. dolichostachya* Moss) from

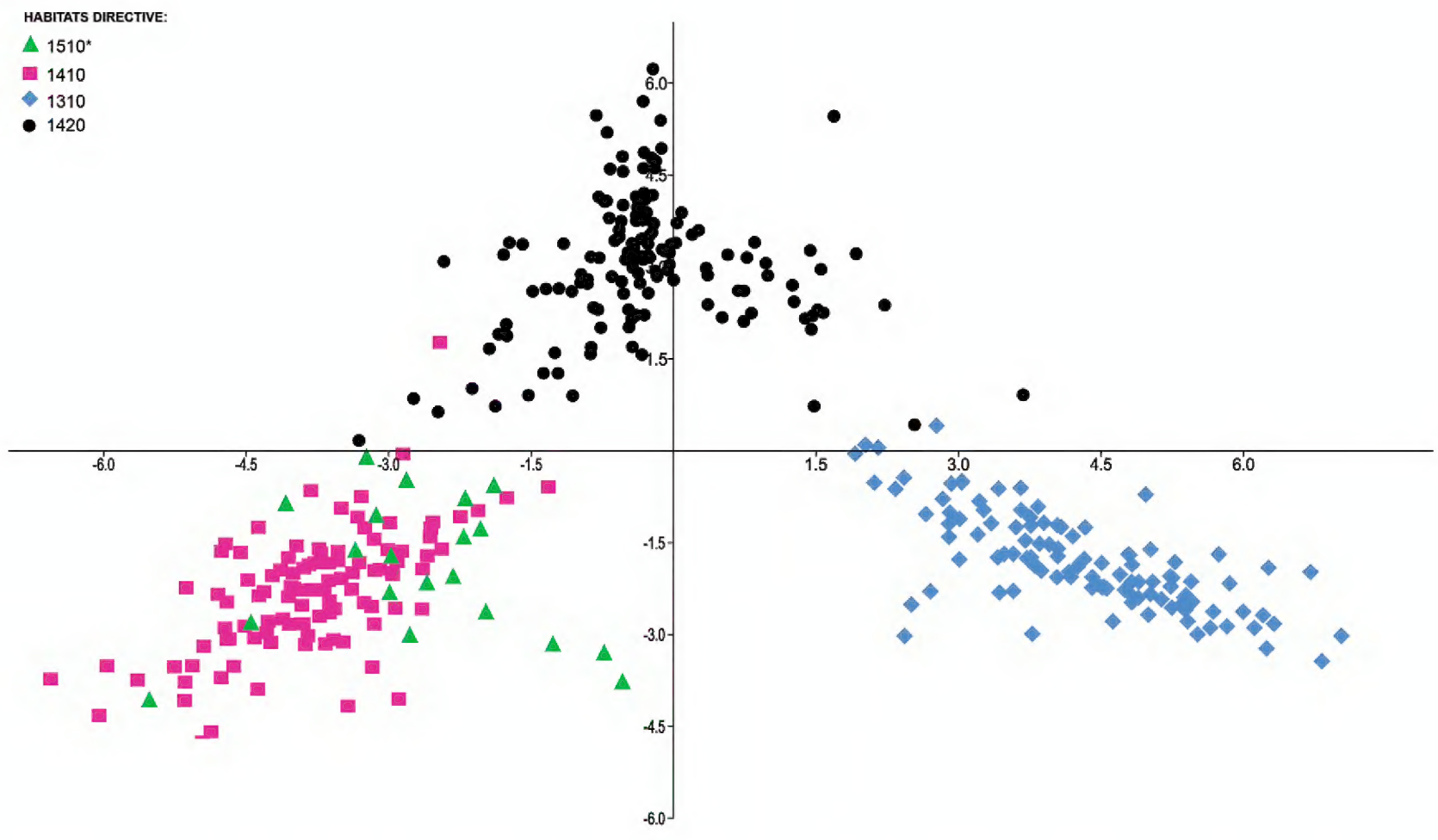

Figure 2. Scatterplot of the LDA (Linear Discriminant Analysis) for the groups of relevés referred to the coastal saline habitats of Tuscany according to the Habitat Directive.

northern (Bertacchi et al. 2021), central (Viciani and Lombardi 2001) and southern areas (Andreucci and Castelli 2001; Andreucci 2004). Other associations referred to the class *Saginetea maritimae*, order *Frankenietalia pulverulentae*, reported for Orbetello (Andreucci 2004), Pianosa (Foggi et al. 2008), Gorgona (Viciani et al. 2011) and Giannutri (Foggi et al. 2011). Only one association relative to the class *Crypsietea aculeatae* was reported: *Crypsietum aculeatae* (Bojko 1932) Wenzl 1934 (Viciani and Lombardi 2001; Bertacchi et al. 2021). Several phytocoenoses referred to this class were reported also for Corsica (Paradis and Lorenzoni 1994). However, they were included in the habitat 3170 (Mediterranean temporary ponds) by Bensettiti et al. (2002), pointing towards the need for further investigations. Most vegetation types of the habitat 1310 need an update from the nomenclatural point of view due to the several novelties in the taxonomy of the *Salicornia* L. genus.

Habitat 1410: For this habitat, nine vegetation types were reported for Tuscany. All these vegetation types can be referred to one class and one order: *Juncetea maritimi* and *Juncetalia maritimi*, and further to three alliances: *Limonion etrusci*, *Juncion maritimi,* and *Plantaginion crassifoliae*. These findings confirm a high homogeneity of this habitat along the coast of Tuscany, even though the floristic composition is not always useful to separate it from the habitat 1420 (see also Fig. 2 where a little overlap with 1420 was found). However, the two habitats differed in their physiognomic configuration: 1410 is dominated by rushes and sedges, while 1420 is dominated by succulent shrubs or subshrubs. A succulent subshrub like *Limbarda crithmoides* subsp. *longifolia*, is generally reported as "typical" for the habitat 1410, which is confirmed by our results (phi = 48). Furthermore, *Limbarda crithmoides* subsp. *longifolia* was chosen as characteristic of the association *Limbardo crithmoidis-Limonietum etrusci* (Viciani et al. 2012). Mucina et al. (2016) assigned the alliance *Limonion etrusci*, for which the association is the nomenclatural type, to the order *Juncetalia maritimi*. Accordingly, *Limbarda crithmoides* subsp. *longifolia* should be selected as a suitable "typical species" for the habitat 1410. In the habitat 1410, two invasive alien species were found: *Symphyotrichum squamatum* (phi = 21.1) and *Xanthium italicum* (phi = 20.5), indicating an unfavourable state of conservation of this habitat in the studied region.

Habitat 1420: According to our results, this is a highly homogeneous habitat within one class, one order (*Salicornietea fruticosae* and *Salicornietalia fruticosae*, respectively) and two alliances: *Salicornion fruticosae* and *Arthocnemion glauci*. Only three associations were found.

Habitat 1510: According to our results (Fig. 2) and from a strictly phytosociological point of view, we propose that the communities dominated by *Limonium narbonense*, should be included in the order *Juncetalia maritimi* instead of *Limonietalia* (as reported by Viciani et al. 2012). Our proposal is based on the absence of *Limonietalia* species, except for *Limonium narbonense*. The same is true for the alliance *Limonion etrusci* (Viciani et al. 2012), that according to Mucina et al. (2016) was classified to the order *Juncetalia maritimi*. The coenoses with *Limonium etruscum*, previously referred to 1510 by Viciani et al. (2012), were here included in the habitat 1410.

Syntaxonomical scheme for high ranks, according to Mucina et al. (2016). Reference to habitats is indicated in brackets.

THEROSALICORNIETEA Tx. in Tx. et Oberd. 1958 (**habitat 1310**)
THEROSALICORNIETALIA Pignatti 1952
Therosalicornion Br.-Bl. 1933

SAGINETEA MARITIMAE Westhoff et al. 1962 (**habitat 1310**)
SAGINETALIA MARITIMAE Westhoff et al. 1962
Saginion maritimae Westhoff et al. 1962
FRANKENIETALIA PULVERULENTAE Rivas-Mart. ex Castroviejo et Porta 1976
Frankenion pulverulentae Rivas-Mart. ex Castroviejo et Porta 1976

CRYPSIETEA ACULEATAE Vicherek 1973 (**habitat 1310**)
CRYPSIETALIA ACULEATAE Vicherek 1973
Cypero-Spergularion salinae Slavnic 1948

JUNCETEA MARITIMI Br.-Bl. in Br.-Bl. et al. 1952 (**habitat 1410**)
JUNCETALIA MARITIMI Br.-Bl. ex Horvatić 1934
Juncion maritimi Br.-Bl. ex Horvatić 1934
Plantaginion crassifoliae Br.-Bl. in Br.-Bl. et al. 1952
Limonion etrusci Viciani et al. 2012
Limonium narbonense community (**habitat 1510**)

SALICORNIETEA FRUTICOSAE Br.-Bl. et Tx. ex A. Bolòs y Vayreda et O. de Bolòs in A. Bolòs y Vayreda 1950 (**habitat 1420**)
SALICORNIETALIA FRUTICOSAE Br.-Bl. 1933
Salicornion fruticosae Br.-Bl. 1933
Arthrocnemion glauci Rivas-Mart. et Costa M. 1984

Local assembly of typical species

Results of the phi analysis are shown in Tab. 1. In Tabs 2-5, we report the "local assembly of typical species" according to the above-mentioned rules.

Habitat 1310: Among the species found in this habitat (N = 82), the "local assembly of typical species" included 12 species with phi > 20 and 2 species with a cover coefficient > 50. This result might be related to the heterogeneity of this habitat. Among the species with phi > 10, we found *Soda inermis* (Tab. 2) with a very low coefficient value. According to our results, many of the species reported as "typical" in Biondi and Blasi (2009), European Environment Agency (2021) and Angelini et al. (2016) cannot be considered for Tuscany. Our results suggest that

Table 1. Diagnostic species of the habitats based on fidelity (Phi-coefficient) ($p < 0.01$) of association on presence/absence data.

Habitats directive	**1310**	**1410**	**1420**	**1510**
Number of relevés	**121**	**109**	**166**	**22**
Salicornia procumbens Sm.	41.2	.	.	.
Suaeda maritima (L.) Dumort.	38.8	.	.	.
Frankenia pulverulenta L.	33	.	.	.
Salicornia perennans Willd.	32.3	.	.	.
Spergularia media (L.) C. Presl	28.1	.	.	.
Parapholis filiformis (Roth) C.E. Hubb.	25.2	.	.	.
Parapholis strigosa (Dumort.) C.E. Hubb.	24.4	.	.	.
Spergularia marina (L.) Besser	23.2	.	.	.
Salicornia fruticosa (L.) L.	22.9	.	.	.
Mesembryanthemum nodiflorum L.	22.5	.	.	.
Silene sedoides Poir.	21	.	.	.
Thinopyrum junceum (L.) Banfi	20	.	.	.
Plantago coronopus L.	19.8	.	.	.
Catapodium balearicum (Willk.) H. Scholz	19.4	.	.	.
Limonium planasiae Pignatti	19.4	.	.	.
Soda inermis Fourr.	19.4	.	.	.
Avena sterilis L. s.l.	17.7	.	.	.
Catapodium pauciflorum (Merino) Brullo, Giusso, Miniss. & Spamp.	17.7	.	.	.
Erigeron sumatrensis Retz.	17.7	.	.	.
Lolium multiflorum Lam.	17.7	.	.	.
Catapodium rigidum (L.) C.E. Hubb.	15.8	.	.	.
Erigeron canadensis L.	15.8	.	.	.
Limonium sommieranum (Fiori) Arrigoni	15.8	.	.	.
Polypogon subspathaceus Req.	15.8	.	.	.
Limbarda crithmoides (L.) Dumort. subsp. *longifolia* (Arcang.) Greuter	.	48	.	.
Limonium etruscum Arrigoni & Rizzotto	.	40.9	.	.
Juncus maritimus Lam.	.	40.4	.	.
Sporobolus virginicus (L.) Kunth	.	39	.	.
Juncus acutus L. s.l.	.	36.7	.	.
Schoenus nigricans L.	.	30.4	.	.
Bolboschoenus maritimus (L.) Palla	.	30.2	.	.
Thinopyrum acutum (L.)Banfi	.	27.2	.	.
Carex extensa Gooden.	.	25.1	.	.
Linum maritimum L. s.l.	.	25.1	.	.
Symphyotrichum squamatum (Spreng.) G.L. Nesom	.	21.1	.	.
Sporobolus pumilus (Roth) P.M.Peterson & Saarela	.	20.5	.	.
Xanthium italicum Moretti	.	20.5	.	.
Lotus tenuis Waldst. & Kit. ex Willd.	.	20	.	.
Phalaris arundinacea L. s.l.	.	18.7	.	.
Tripidium ravennae (L.)H.Scholz	.	18.7	.	.
Allium vineale L.	.	16.7	.	.
Atriplex littoralis L.	.	16.7	.	.
Avena barbata Pott ex Link	.	16.7	.	.
Blackstonia acuminata (W.D.J. Koch & Ziz) Domin subsp. *acuminata*	.	16.7	.	.
Dactylis glomerata L. s.l.	.	16.7	.	.
Tamarix gallica L.	.	16.7	.	.
Galatella tripolium (L.) Galasso	.	13.5	.	.
Juncus gerardii Loisel.	.	12.9	.	.
Aeluropus littoralis (Gouan) Parl.	.	11.5	.	.
Inula viscosa (L.) Aiton	.	10.6	.	.
Salicornia perennis Mill.	.	.	42.9	.
Halimione portulacoides (L.) Aellen	.	.	31.3	.
Triglochin barrelieri Loisel.	.	.	18.9	.
Puccinellia festuciformis (Host) Parl.	.	.	17.7	.
Limonium narbonense Mill.	.	2.9	.	69.7
Artemisia caerulescens L. subsp. *caerulescens*	.	.	.	47.8
Bupleurum tenuissimum L.	.	.	.	35.4
Hordeum marinum Huds.	5.6	.	.	32.3
Atriplex sp.	.	.	.	29.8
Phragmites australis (Cav.) Trin. ex Steud. s.l.	.	9.9	.	25.4

Table 2. "Local Assembly of Typical Species" for habitat 1310. N = number of presence; % = frequency; phi = phi-coefficient (based on presence/absence data); CV= cover coefficient; "typical species" as results from: BB = Biondi and Blasi (2009); EEA = European Environment Agency (2021); EC = European Commission (2013); A & al. = Angelini et al. (2016); RT = Regione Toscana (2018).

Numbers of relevés: 122	**presence**	**%**	**phi**	**CV**	**BB**	**EEA**	**EC**	**A & al.**	**RT**
Salicornia procumbens Sm.	27	22.31	41.2	871.3	x		sub: Salicornia sp. pl.	sub: Salicornia sp. pl.	sub: Salicornia sp. pl.
Suaeda maritima (L.) Dumort.	43	35.54	38.8	509.6	x	x	sub: Suaeda sp. pl.	x	x
Frankenia pulverulenta L.	17	14.05	33.0	359.2	x	x		x	x
Salicornia perennans Willd.	39	32.23	32.3	1234.1	sub: *Salicornia* sp. pl.	sub: *Salicornia* sp. pl.	sub: *Salicornia* sp. pl.	sub: *S. patula*	sub: *S. patula*
Spergularia media (L.) C. Presl	18	14.88	28.1	293.9	x			x	x
Parapholis filiformis (Roth) C.E. Hubb.	10	8.26	25.2	120,00				x	x
Parapholis strigosa (Dumort.) C.E. Hubb.	21	17.36	24.4	734.6	x	x			
Spergularia marina (L.) Besser	21	17.36	23.2	56.6	x	x		x	x
Salicornia fruticosa (L.) L.	21	17.36	22.9	35.1					
Mesembryanthemum nodiflorum L.	8	6.61	22.5	218.9				x	x
Silene sedoides Poir.	7	5.79	21,00	84.9	x			x	x
Thinopyrum junceum (L.)Banfi	13	14.29	20,00	23.6					
Plantago coronopus L.	29	23.97	19.8	302.6					
Soda inermis Fourr.	12	9.92	19.4	73.3		sub: *Salsola soda*		x	x

species, previously considered as typical for the studied habitats in regional sources, cannot be applied at the local level in Tuscany. We found one invasive alien species: *Erigeron canadensis* with phi = 15.8 and a cover coefficient > 50, that, at least locally, indicated a low conservation status of habitat 1310.

Habitat 1410: The habitat 1410 was rich in species (N = 91). This finding is also reflected by the large number of species that meet the above defined criteria of the "local assembly of typical species". Among both, the own relevés and the relevés derived from literature allocated to 1410, 13 species had a phi > 20, and two species reached a phi > 10 and a cover coefficient > 50 (Tab. 3).

Habitat 1420: The "local assembly of typical species" for the habitat 1420 included very few species. Only three of them (*Salicornia perennis*, *Arthrocaulon macrostachyum*, *Halimione portulacoides*) showed medium-high phi-values (phi > 30) but a high coefficient value (> 1500). These species were succulent (low-)shrubs characterizing the habitat also from a physiognomic point of view (Tab. 4). We found two more species with a coefficient value > 50: *Puccinellia festuciformis*, generally used as characteristic species of several associations referred to this habitat, and *Triglochin barrellieri*.

Habitat 1510: As already stated, the relevés allocated to the habitat 1510 were found in the area delimited by the relevés of the habitat 1410. However, the constant presence of *Limonium narbonense* with very high phi-values (phi = 69.7) and a high coefficient value (> 6000), pointed towards the attribution of habitat 1510, defined as rich in perennial species of the genus *Limonium* (Biondi and Blasi 2009) (Tab. 5). The habitat 1410 is linked to humid depressions and is dominated by species of rushes belonging to the genus *Juncus* (Tab. 4). *Juncus* species are generally absent at sites located at higher topographic levels, where the habitat 1510 can be found. In this topographic position, the sites remain generally dry during the whole year and are intensively grazed by cattle. The peculiarities of habitat 1410 call for conservation practices markedly different from the current once. Therefore, to help local authorities in identifying and monitoring the implemented conservation measures, habitat 1410 needs to be addressed separately.

In the habitat 1510, *Phragmites australis* was found among the species with a phi > 10 (25.4) and with a coefficient value > 50. However, *P. australis* cannot be included in the "local assembly of typical species" because it was also found in other communities, with higher values of phi and/or coefficient value. Here the species must be considered as a negative presence.

Conclusions

The main aim of this paper was to assess the phytosociological classification of saline vegetation of Tuscany at the alliance level. From a phytosociological point of view, the relevés dominated by *Limonium narbonense* and those with *Limonium etruscum*, previously assigned to the order *Limonietalia* in Viciani et al. (2012), were here allocated to the order *Juncetalia maritimi*. Secondly, we identified groups of species that we indicate as suitable for the rec-

ognition and monitoring of the saline EU Habitats present along the Tuscany coast: 1310, 1410, 1420 and 1510. We defined these groups of species as "local assembly of typical species". In our study, the "local assembly of typical species" was identified by means of qualitative and quantitative data. Species with high cover coefficient can be useful to recognize the habitat, while species with high phi values can be defined as species to be monitored. Accordingly, the "local assembly of typical species" consists of all species with a phi > 20 and/or cover > 50%. Results showed that in certain habitats the two categories can coincide, as in habitat 1420 and 1510. On the contrary, the "local assembly of typical species" of habitat 1310, included a high number of vegetation types, also belonging to a higher syntaxonomical level. Here we found many species with low phi value and coefficient value.

The low number of species and the strong ecological homogeneity of these habitats, apart from habitat 1310, suggest that this approach should be performed on for-

Table 3. "Local Assembly of Typical Species" for habitat 1410. N = number of presence; % = frequency; phi = phi-coefficient (based on presence/absence data); CV= cover coefficient; "typical species" as results from: BB = Biondi and Blasi (2009); EEA = European Environment Agency (2021); EC = European Commission (2013); A & al. = Angelini et al. (2016); RT = Regione Toscana (2018).

Numbers of relevés: 109	**n**	**%**	**phi**	**CV**	**BB**	**EEA**	**EC**	**A & al.**	**RT**
Limbarda crithmoides (L.) Dumort. subsp. *longifolia* (Arcang.) Greuter	45	41.7	48.0	575.6	x	x			
Limonium etruscum Arrigoni & Rizzotto	22	20.4	40.9	366.1		x			
Juncus maritimus Lam.	38	35.2	40.4	1341.8	x	x	x	sub: *Juncus* sp. pl.	x
Juncus acutus L. s.l.	42	38.9	36.7	1483.4	x	x	x	sub: *Juncus* sp. pl.	x
Schoenus nigricans L.	12	11.2	30.4	48,0	x	x		x	
Bolboschoenus maritimus (L.) Palla	14	13.0	30.2	69.5					
Thinopyrum acutum (L.) Banfi	25	23.2	27.2	338.3	sub: *Agropyrum pungens*				sub: *Elytrigia atherica*
Carex extensa Gooden.	11	10.2	25.1	10.3	x	x	x	x	x
Linum maritimum L. s.l.	9	8.4	25.1	12.1	x	x	x		
Sporobolus virginicus (L.) Kunth	20	18.6	39	73.48		x			
Juncus gerardii Loisel.	23	21.3	12.9	539.7	x	x	x	sub: *Juncus* sp. pl.	x
Aeluropus littoralis (Gouan) Parl.	18	16.7	11.5	322.1	x	x	x		

Table 4. "Local Assembly of Typical Species" for habitat 1420. N = number of presence; % = frequency; phi = phi-coefficient (based on presence/absence data); CV= cover coefficient; "typical species" as results from: BB = Biondi and Blasi (2009); EEA = European Environment Agency (2021); EC = European Commission (2013); A & al. = Angelini et al. (2016); RT = Regione Toscana (2018).

Numbers of relevés: 166	**n**	**%**	**phi**	**CV**	**BB**	**EEA**	**EC**	**A & al.**	**RT**
Salicornia perennis Mill.	68	41.0	42.9	2910.7	x	x	sub: *Sarcocornia perennis*	sub: *Sarcocornia* sp. pl.	sub: *Sarcocornia perennis*
Arthrocaulon macrostachyum (Moric.) Piirainen & G. Kadereit	40	24.1	33.8	1647.5	x	x	x	sub: *Arthrocnemum* sp. pl	x
Halimione portulacoides (L.) Aellen	40	24.1	31.3	2117.8	x	x	x		x
Puccinellia festuciformis (Host) Parl.	51	30.7	17.7	253.8	x	x			
Triglochin barrelieri Loisel.	13	7.8	18.9	187.7	x				

Table 5. "Local Assembly of Typical Species" for habitat 1510. N = number of presence; % = frequency; phi = phi-coefficient (based on presence/absence data); CV= cover coefficient; "typical species" as results from: BB = Biondi and Blasi (2009); EEA = European Environment Agency (2021); EC = European Commission (2013); A & al. = Angelini et al. (2016); RT = Regione Toscana (2018).

Number of relevés: 22	**n**	**%**	**phi**	**CV**	**BB**	**EEA**	**EC**	**A & al.**	**RT**
Limonium narbonense Mill.	22	100.0	69.7	6213.6	x	x	sub: *Limonium* sp. pl.	sub: *Limonium* sp. pl.	x
Artemisia caerulescens L. subsp. *caerulescens*	10	45.5	47.8	502.3	x				
Bupleurum tenuissimum L.	4	18.2	35.4	272.7		x			
Hordeum marinum Huds. s.l.	6	27.3	32.3	193.6		x			
Atriplex sp.	3	13.6	29.8	22.7					

est and grassland habitats to test its applicability on more complex habitats.

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Supplementary material 1

Tables S1

Authors: Matilde Gennai, Claudia Angiolini, Andrea Bertacchi, Antonio Gabellini, Simona Sarmati, Daniele Viciani, Bruno Foggi

Data type: table

Explanation note: Matrix used in the study. Nomenclature is according to ActaPlantarum.

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Link: https://doi.org/10.3897/PlantSociology.59.78067.suppl1

Supplementary material 2

Tables S2

Authors: Matilde Gennai, Claudia Angiolini, Andrea Bertacchi, Antonio Gabellini, Simona Sarmati, Daniele Viciani, Bruno Foggi

Data type: list

Explanation note: Literature from which we selected the relevés and data of plots concerning the salt marsh vegetation of Tuscany.

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